Aerosol Microphysics and Radiation Integration

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LONG-TERM GOALS

This project is one of several working toward the goal of providing the Department of Defense and civilian research community with a real time global prognostic aerosol and visibility model. Overall, the nature of aerosol particle light extinction and absorption in the marine environment is highly variable throughout the world. Typically there is only fair visibility in many sensitive parts of the globe, including the Persian Gulf/Arabian Sea, East Asia, and some parts of the Mediterranean Sea. Along coastal regions, dust, pollution and smoke can be present and dominate Electro-Optical (EO) effects over simple sea salt. To model such complicated environments, process models such as the NRL Aerosol Analysis and Prediction System (NAAPS) require precise source and sink function as well as parameterizations for particle size, chemistry, and optical properties. As these parameters are key for the proper validation of the model, this work unit also takes the leading role for aerosol model validation (such as for NAAPS).

Ultimately, generated aerosol parameterizations will be transitioned into Navy transport and EO propagation models. A sub-goal is the development of validation methods that adequately and fairly test these models. Finally, through the analysis of global geochemical cycles, fate analyses and atmospheric chemical processes, the role of aerosol particles in the atmosphere will be studied and understood. An aerosol climatology suitable for EO systems analysis will be developed.

OBJECTIVES

The objective of this program is to investigate, develop, and test aerosol microphysical and radiative properties and parameterizations to be used in Navy aerosol models and remote sensing retrievals. The ultimate goal of the program is to develop a set of aerosol particle microphysical parameterizations and source functions that are consistent chemically, microphysically and optically so that Navy systems can better predict the atmospheric electro-optic environment.

APPROACH

This project requires the simultaneous study of model, remote sensing, and field data. Based on all three data sources, physically consistent sets of particle parameterizations are generated. These parameterizations include source and sink functions (dry/wet deposition), particle size parameterizations, particle chemistry, and optical properties such as mass extinction efficiency, single-scattering albedo, and phase function. The open literature is closely studied so that state-of–the-art

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scientific knowledge can be applied to meet navy aerosol needs with a minimum of duplicated effort. When necessary, field measurements are made to test hypotheses and measure key parameters. The principal test beds for this research are the NRL Aerosol Analysis and Prediction System (NAAPS) and the Coupled Ocean/Atmosphere Prediction System (COAMPS^{TM}). Long-term climatologies developed under related ONR/NRL programs are analyzed and compared to field and remote sensing data. Any detected bias is investigated and related to source functions, microphysics, or radiation causes.

WORK COMPLETED

In FY03 this project transitioned from the combined Marine Aerosol and Dust Aerosol programs from SPAWAR Systems Center San Diego (SSC-SD) to the Naval Research Laboratory, Marine Meteorology Division, Monterey CA. During a 3-month transition period, equipment was re-inventoried, calibrated and, where needed, maintenance provided. Computer systems were transferred, including real time data analysis systems and web sites.

During FY03 the Mobile Atmospheric Aerosol and Radiation Characterization Observatory (MAARCO), was developed. This mobile laboratory, manufactured from a standard 20' shipping container, houses a set of meteorological, radiation and aerosol instrumentation. The container can be shipped to almost any site in the world to be used as a research station and it can be operated onboard oceanographic or research vessels. This year a NASA-manufactured micro-pulse lidar (MPL) and an Aerosol Robotic Network (AERONET) Sun photometer were installed and quality assured. A complete set of radiometers, aerosol particle samplers and sizers, and gas phase instruments were also installed, along with an inlet/aerosol plumbing system. It is the intent of NRL to deploy MAARCO to sites of interest during specific field campaigns.

MAARCO first reached operational status during the Asian Dust Above Monterey (ADAM) field campaign during April of 2003 in Monterey, CA. The goals of ADAM were to characterize the physical and radiative properties of the aged Asian dust and pollution that reaches the United States West Coast. This mission was also used to test the predictability skill of the Navy Aerosol Analysis and Prediction System (NAAPS), and to test newly acquired surface and airborne instrumentation. During the mission, the CIRPAS Twin Otter research aircraft was utilized, as well as a number of ground sites.

This work unit contributed to the ADAM campaign by taking the lead role in investigating Asian aerosol particle characteristics. In addition to wing probe data from the Twin Otter, aerosol particles were collected on filters for analysis. Twenty Teflon and polycarbonate filters were exposed during the mission. These were subsequently analyzed by X-ray florescence, ion chromatography, and atomic absorption spectroscopy under contract with the Desert Research Institute, and individual particle analysis was conducted at the University of California at Davis. A continuous sampling cascade impactor contracted from UC Davis was deployed at the Monterey Institute for Research in Astronomy's observatory at Chews Ridge (near Monterey) to sample free troposphere air. Strips from this impactor were subsequently analyzed at the Lawrence Berkley labs Advanced Light Source. Preliminary Quality assurance has been initiated on all of these data.

Analysis of aerosol data from the Rough Evaporation Duct (RED) Experiment was ongoing throughout the year. Eddy correlation estimates of sea salt source functions from the Research Platform FLIP

were generated and presented at the 2003 American Meteorological Society meeting. Sea salt particle size distributions were also analyzed, and likely biases in the peer-reviewed literature were detected and duplicated. We continue to coordinate our efforts with NRL DC's program (Peter Caffery, PI) to use COAMPS data to analyze aerosols in the marine environment.

Work continues in the joint ONR 322/NASA interdisciplinary science Fire Locating and Modeling of Burning Emissions (FLAMBE) project, which also provides NAAPS with a real-time biomass burning source function. In FY03, MODIS fire products were added to the system, subsequently providing NAAPS with global coverage for smoke. The South American continent was analyzed for the year 2001 to validate the emissions, microphysics and transport models.

Lastly, new methods were developed to analyze NAAPS data. Semi-automated routines are being developed to compare NAAPS output files to the Aerosol Robotic Network (AERONET) global network of sun photometers, and to archived MODIS Level-3 optical depth files.

RESULTS

While the ADAM campaign has just been completed and only limited analysis of data has taken place, interesting preliminary results have already been generated. Single particle analysis of particle size and morphology has shown that Asian dust that has undergone long-range transport is significantly different from its African/Saharan counterparts. This disparity is likely due to differences in transport mechanism. Mean dust particle size is relatively small and, unlike African dust, secondary production of sulfate is clearly evident on the particles. Through receptor modeling analysis, we find supporting evidence for an early forecast prediction that dust from the now infamous March 24th 2003 Iraqi dust event did in fact reach the west coast of the United States.

The analysis of the RED experiment data set is almost completed, and we have begun writing manuscripts with our results. At present there are three important results. We have the first ever eddy correlation measurements of coarse mode sea salt source functions. This significantly constrains previous estimates in the literature that vary by over an order of magnitude. We have also identified a significant bias in reported sea salt particle size the peer-reviewed literature (this is similar to a finding we had in FY02 on dust particles). Most optical particle counter data (which makes up the bulk of the research database) overestimates particle size by almost a factor of two, greatly altering some previous conclusions on the marine atmosphere. Further, expected size increases with increased humidity at cloud base are not well reflected in the data. From these preliminary studies, it is clear that the biggest uncertainty in many indirect forcing studies is in the instruments themselves.

With the integration of MODIS data into the NAAPS smoke source function, the monitoring of intercontinental smoke plumes in real time is now possible. In the year 2003, we correctly identified significant impacts of smoke on US air quality from fires originating from Siberia and Central America. Transport mechanisms were identified. Also in this fiscal year, we assessed the performance of the smoke component in NAAPS for South America, and have shown that despite issues of fire ambiguity and cloud cover, real-time hot spot analysis can be successfully used to specify the smoke source in a model. Correlations of smoke optical depth from the model were good on both monthly and short (2-day) time scales. Derived emissions for South America were on the order of ~25+10 Tg yr^{-1}; close to values presented in the literature, and hence showing consistency with other work. We also show that under some circumstances, there may be bias in the MODIS level 3 data.

Most importantly, clear sky bias in satellite data may be masking relevant transport patterns in the ITCZ and South Atlantic Ocean. This subject will no doubt result in errors and biases in the estimations of indirect effects using remote sensing analysis.

IMPACT/APPLICATIONS

Research under this work unit has already begun to significantly affect the aerosol science community. Our findings on dust microphysics are currently being incorporated into several aerosol models in the research community. We have shown that most of the coarse mode sea salt and dust particle size distributions presented in the literature are suspect and hence so are many subsequent model validation studies. Our sea salt source functions significantly constrain estimates in the literature.

TRANSITIONS

Fire products (including fluxes and transport data) from the joint ONR 32/NASA Fire Locating and Modeling of Burning Emissions (FLAMBE) project are currently being utilized by internet community, Air quality/human health research (University of Kansas Medical Center), Environment Canada – Quebec Region Pacific Northwest Laboratory, Dept. of Energy for ARM program research, State of Chiapas Dept. of Civil Protection for fire assessment, the Texas Environmental Board for regional air quality, and the University of Newcastle, Australia for aviation forecasting.

RELATED PROJECTS

This project is closely tied to other work units at NRL Monterey. Products and validation work feed directly into the ONR 6.2 project Coastal Aerosol Distribution by Data Assimilation (Douglas L. Westphal, PI) for further development of NAAPS. Also, this project is tied to two joint ONR/SPAWAR Rapid Transition Program (RTP) projects: Improvement of Aerosol Prediction Capability (FY01-FY03) and Slant Path Visibility (FY03-FY05). Validation methods developed under this project are employed under the RTP, as well as updated aerosol parameterizations and radiative transfer schemes. Lastly, we work closely with NRL Satellite and Radiation Branch's research on marine aerosol modeling.

PUBLICATIONS

(a) Peer Reviewed Publications

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HONORS/AWARDS/PRIZES

Bucholtz, A., NRL 2003 Technology Transfer Award, 'Development of a Stable Platform for Airborne Radiometric Measurements.'

Bucholtz, A. (as member of CRYSTAL-FACE Science Team), NASA 2003 Group Achievement Award to CRYSTAL-FACE Science Team

Reid, J. S., 2002 Editors' Citation for Excellence in Refereeing for Journal of Geophysical Research-Atmospheres